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Trail Degradation Along The Pat Sin Range: An Example of Environmental Geomorphology

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Abstract

This study investigated the extent, forms and environmental relationships of trail degradation along the Pat Sin Range in the New Territories of Hong Kong. Results showed that the trail was in good condition except for a few localities. There were significant poositive relationships between slope gradient and different degradation measures, though the strength of these relationships varied greatly between volcanic and sedimentary parent rocks. Implications for country park and trail management are discussed in light of these research findings.

摘要

本研究旨在調查香港新界八仙嶺遠足山徑的侵蝕退化狀況、特點、及其與環境的關係。結果顯示除個別地點以外，此山徑的退化情況並不算嚴重。多種退化指標均與山徑坡度有顯著的正關係，而此關係的強度卻在火山岩和沉積岩之間存在很大的差異。我們根據本研究的結果，對郊野公園及山徑管理提出了一些建議。

Introduction

The earth sciences are pertinent to many aspects of environmental management and perhaps this is no where better illustrated than in Hong Kong. Within the urban context, engineering geology, land planning, slope stability, underground constructions and waste management are a few of the many areas within which earth scientists have played major roles. However, the discipline can also contribute to the management of the surrounding non-urban countryside. Indeed one of the neglected applications of earth sciences in environmental management has been the management of country parks in the Territory.

Unfortunately, high visitation rates to Hong Kong's country parks causes detrimental impacts on the resource components that constitute the very environment to which visitors are attracted. Fire, trampling, littering and vandalism have major adverse impacts (Jim, 1986). These problems are further exacerbated by the uneven patterns of patronage, both spatially and temporally (Jim, 1989).

Trails (footpaths) are the main travel arteries within Hong Kong's country parks and many of these were created by villagers for convenience rather than with recreation or resource protection in mind. Many of these have degraded over time because of poor initial siting, recreational overuse and a lack of maintenance. The degradation of such trails represents a depletion of a non-renewable resource and a failure to maintain the character of an area. They are an eyesore, are unsafe, and are costly to repair. Erosional material from trail treads can also be a significant source of sediment which may cause adverse effects on aquatic life. Whilst aspects of trail degradation have been mentioned recurrently in Hong Kong, there remains a lack of published objective information that unfortunately precludes any systematic evaluation of the severity of the problem. This article therefore attempts to characterise the extent and forms of degradation of trails within the Pat Sin Leng Country Park in Hong Kong as an example of how earth scientists, particularly geomorphologists, can contribute to environmental management.

Study Area

This study focuses on the degradation of trails (compaction, widening, incision, erosion and multiple treads; as defined by Leung and Marion, in press) along the Pat Sin Range in the New Territories of Hong Kong (Figure 1). This is one of the most popular hiking routes in the Territory because of the out-

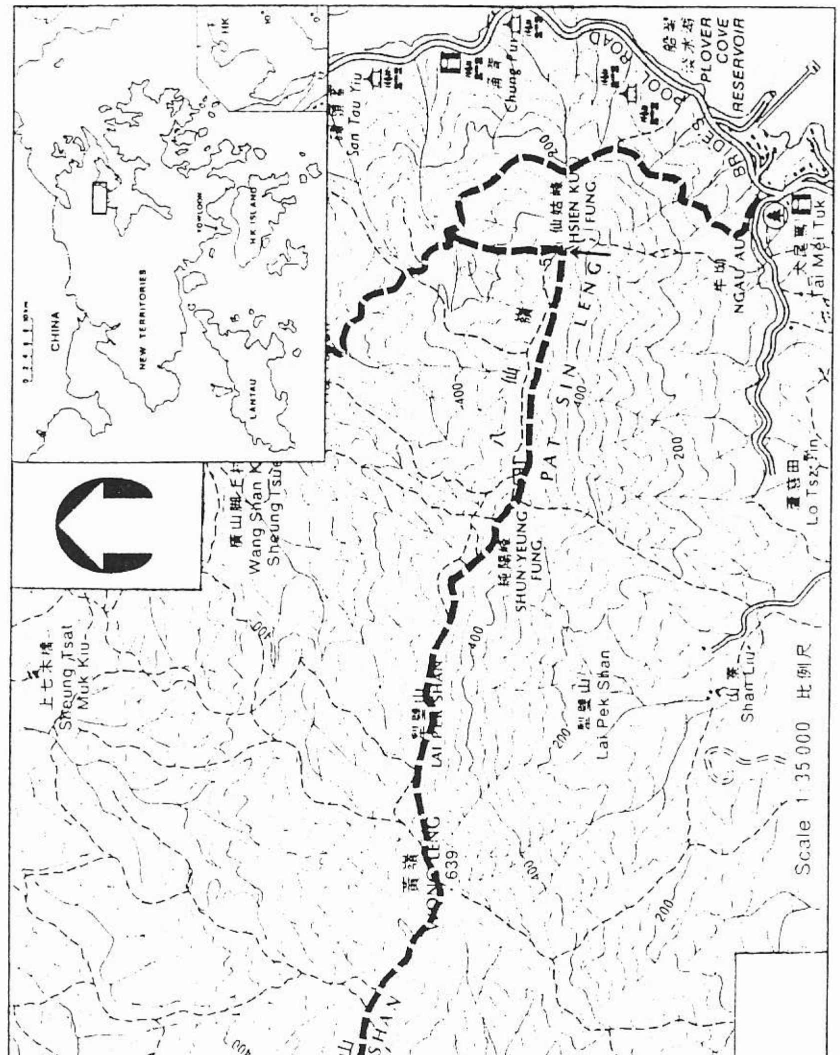

Figure 1: Location of the Pat Sin Range Trail.

standing panoramic views. The country park features an escarpment dramatically rising from the northwest shores of Tolo Harbour. The trail traverses a number of ridges and provides a variety of relief, from level passes to steep slopes. The total length of the trail is eight kilometres, though this study focused on the six kilometres from Hsien Ku Fung to Ping Fung Shan (Figure 1).

The Pat Sin Range area is underlain by both volcanic rocks (coarse ash crystalline tuff) at Pat Sin Leng and sedimentary rocks (conglomerates, sandstones and siltstones) west of Lei Pek Shan. Weathering has proceeded more intensely on the volcanic rocks leading to a more developed red-yellow podsol, as opposed to the skeletal lithosols typical of the sedimentary areas (GCO, 1988). Vegetation is dominated by *Rhodomyrtus tomentosa* and *Arundinella nepalensis* on the volcanic rocks, whilst on the sedimentary rocks vegetation is characterised by *Baeckea frutescens*, *Dicranopteris dichotoma* and *Lepidosperma chinensis*.

Methods

A post-impact cross-sectional research approach was by necessity adopted. At systematically selected sample sites along the trail (100 metre intervals), degradation indicator variables were measured simultaneously on the trail and at adjacent off-trail control sites. Degradation indicators that were measured included penetration resistance (absolute and relative changes), trail morphology (width, incision, form), trail surface (roughness, cover) and the presence of multiple trails. Various site condition variables were also measured: trail and terrain slopes, aspect, position, underlying materials, textural characteristics, aggregate stability, pH and organic carbon. Of the 58 sample sites 23 were located on rocks of volcanic origin. Further details on the methods and procedures employed are available in Leung (1992).

Degradation Condition

There was considerable variability in width along the trail, from a 34 cm single tread at Ping Fung Shan, to the combined multi-treads of the Pat Sin Range (total width of 670 cm). Whilst strictly comparable data (similar usage, relief, geology and so on) from elsewhere were lacking, the average tread width of 100 cm along the Pat Sin Trail appears to be unusually wide when compared to a variety of other studies (Table 1). For example, the maximum tread width specified by various forest service departments ranges between 61 and 70 cm (Lucas, 1984; Cole, 1987). Although the Pat Sin Range Trail is not forested, this average figure still appears unusually high. This should be a matter of concern for resource managers, as the trail crisscrosses open grassland, causing visual irritation to recreationalists and exposing bare ground for soil erosion.

In contrast, the average incision depth along the Pat Sin Range Trail is not as great as that experienced in other countries (Table 1). Incision depth ranges between 0 and 26 cm with an average of 3 cm. Whilst there are no published guidelines on acceptable incision depths, comparisons with criteria used by other researchers to classify trails (Bayfield and Lloyd, 1973; Bratton et al., 1979; Cole, 1983a) as either good or poor, reveal that incision depths along the Pat Sin Range Trail are generally good. Incised tread surfaces can function as rills and small gullies within which flows are channelled. Therefore shallow incision depths are desirable.

Multiple treads, or secondary paths, are a form of trail widening and are essentially caused by either actual or perceived difficulties of walking. At only five of the sample sites (8.6%) did more than one tread exist and only at one of these sites were there more than two treads. The lack of multiple treading on the Pat Sin Range Trail can be attributed to steep sideslopes which discourage hikers from wandering off the established trail tread.

The mean penetration resistance recorded at seven locations across each of the 58 trail samples (Figure 2) illustrates that there were few differences amongst the off-trail sites, and few differences amongst the trail tread sites, but that there were major differences between trail tread and off-trail sites. This suggests that once the trail has been established and readily identified by hikers, compaction impact remains localised to the tread surfaces. The absolute compaction levels are not readily comparable with data from other studies (due to differing measurement techniques and soil character) so they were converted to relative changes in penetration resistance between the trail and the surrounding area. Comparisons with a variety of other studies from differing environments within the USA (Table 2) revealed that there is only a small relative rise in compaction along this trail, and that this probably reflects the relatively high penetration resistance of the natural soils.

62% of the sites along the Pat Sin Range were categorised as very stony to extremely stony, though there were clear differences between volcanic and sedimentary terrains. 65% of the sample sites within the volcanic terrain were categorised as moderately stony whereas 80% of the sample sites in the sedimentary terrain were classified as very to extremely stony.

Additional evidence of degradation was observed in the field, including two rutted trail segments that forced hikers to walk either side of the trail, large bare patches at trail junctions (group resting places; Figure 3), stony outwash deposits on steeper slope segments that induced off-trail wandering (due to unpleasant tread surface) and occasional informal short-cut trail segments.

Although the above summary provides valu-

Table 1: Comparison of the results of trail degradation studies in different environments

Trail	Location	Number of Sites	Average Tread Width (cm)	Average Depth (cm)	Average Maximum Depth (cm)	Cross Section Area (cm²)	Data Source
Poor trails in GSMNP[1]	Eastern USA	623	101-113	NA	7.4-7.7	NA	Bratton et al. (1979)
Good trails in GSMNP	Eastern USA	414	40-84	NA	1.2-2.3	NA	Bratton et al (1979)
Bannerman's Hut Path	South Africa	44	62.4	18.0	NA	132	Garland et al. (1985)
Giant's Ridge Path	South Africa	89	49.9	16.7	NA	76	Garland et al. (1985)
Contour Path	South Africa	51	40.7	12.5	NA	54	Garland et al. (1985)
Appalachian Trail	Eastern USA	221	76.5 (2.06)	6.4 (0.29)	NA	312.3 (22.35)	Burde & Renfro (1986)
Pangnirtung Pass	Arctic Canada	25	28.7	4.3	NA	NA	Welch & Churchill (1986)
Big Creek Trail in SBWW[2]	Western USA	10	81 [9]	NA	15 [3]	1155 [43]	Cole (1991)
Pat Sin Range Trail	Hong Kong	58	99.8 (11.39)	3.3 (0.36)	6.7 (0.71)	333.4 (73.38)	Leung (1992)

Note: (fig.) = standard error; [fig.] = 95% confidence interval; NA = not available

[1] GSMNP - Great Smoky Mountain National Park

[2] SBWW - Selway-Bitterroot Wilderness

able information, it would nevertheless be useful in the assessment of trail degradation if park managers were provided with an index that reflects the overall level of degradation indicated by these parameters. This index could also assist in identifying relationships between degradation and environmental site factors. Although an integrated index is not new in recreational impact research, particularly with campsite studies (Marion, 1986), there has been little attempt to produce an index for trail degradation. In this study the z-score standardization method was used, whereby the z scores for tread width, maximum incision depth, cross-sectional area and multiple treading were computed and then summed into a single index, here referred to as the Degradation Score.

The means of the z scores for each parameter were of course zero with a standard deviation of one. When these parameters were combined into a single value the mean of this newly formed Degradation Score remained unchanged, but the median changed to -0.15, indicating that the majority of sites had below average Degradation Scores and that exceptionally high Degradation Scores were limited to only a few sites. Altogether 67% of the sites had Degradation Scores less than zero and 33% had Degradation Scores greater than zero. These later sites can thus be classified as 'degraded' on the basis that the variables representing bare ground, rutting and erosion are above average, though from a management point of view they need not be of immediate concern. The relationship between these degraded sites and the environmental site conditions can now be examined in more detail.

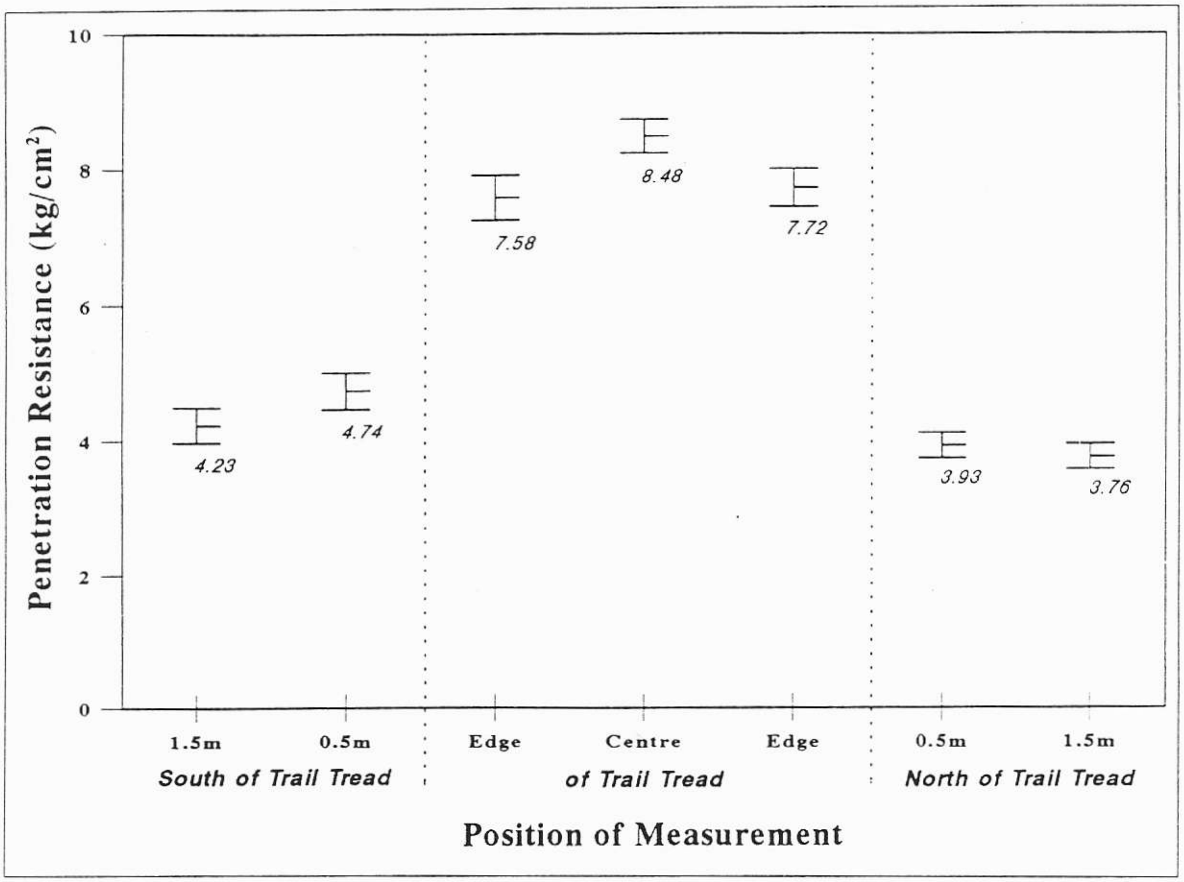

Figure 2 - Mean penetration resistance (± 1 standard error) on and beside the tread of Pat Sin Range Trail.

Table 2: Relative changes of penetration resistance reported in recreation impact studies (using pocket penetrometers)

Geographic Location	Ecosystem Type	Location of Impact	Average Penetration Resistance at Control Sites (kg/cm^2)	Relative Increase in Pen.Res.[1]	Data Source
Michigan USA	Needleleaf Forest	Trail	0.24	14.77	Ward and Berg (1973)
Rhode Is. USA	Oak Forest	Picnic Site	1.25	1.44	Brown et al. (1977)
Montana USA	Subalpine Forest	Campsite	2.20	0.71	Cole (1983b)
Minnesota USA	Needleleaf Forest	Campsite	1.40	1.64	Marion and Merriam (1985)
Arizona USA	Desert Woodland	Campsite	0.70	3.37	Cole (1986)
Hong Kong	Subtropical Grassland	Trail	4.22	1.09	Leung (1992)

[1] The increase in penetration resistance at the impact zone relative to its nearby undisturbed control site.

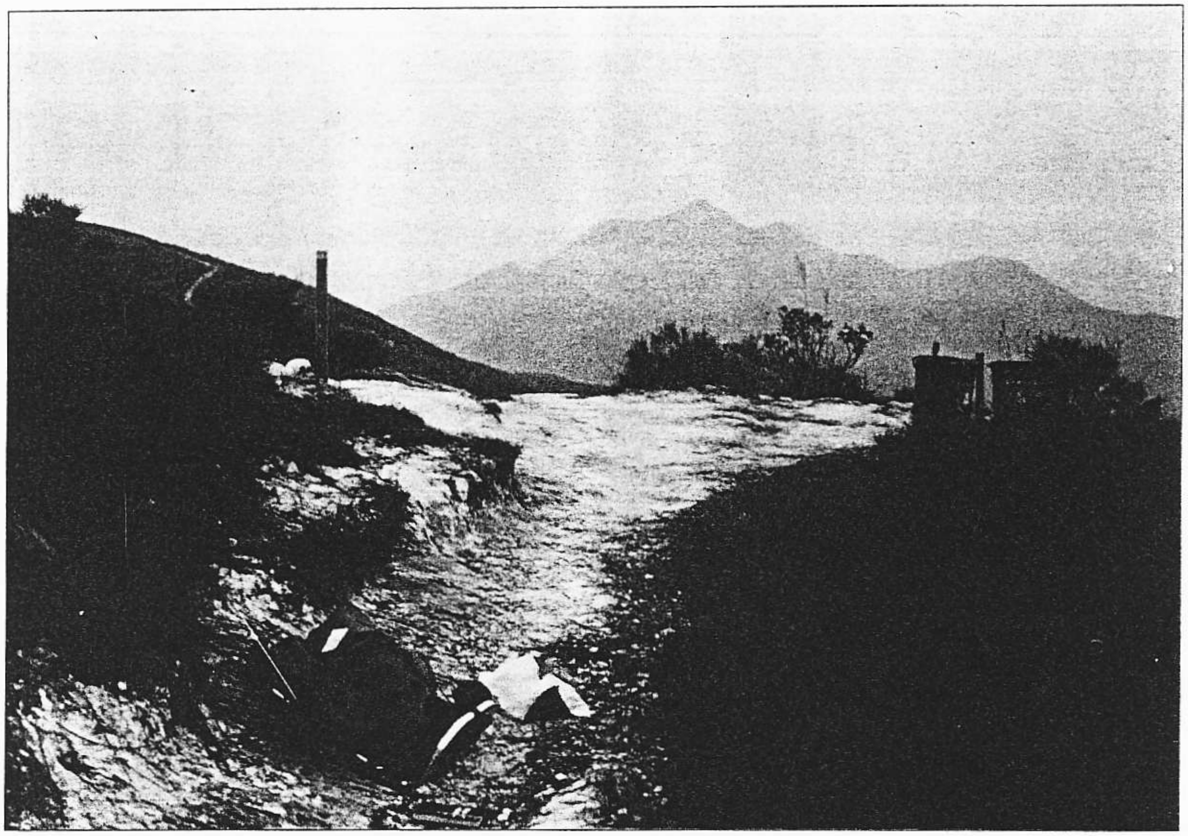

Figure 3 - Extensive soil loss at a trail junction on Ping Fung Shan.

Relationship between Degradation and Site Conditions

(a) Geological and soil factors

The influence of parent material was quite limited in this study area despite two contrasting underlying materials. Firstly, there was little difference in the degree of degradation between the two major rock types, 30% of the volcanic rock sites were classified as degraded as opposed to 34% of the volcanic rock sites. Similarly, there was little relationship between soil properties, such as aggregate stability and clay ratio, and the degree of degradation. This suggests that whilst these soil parameters might be useful indicators for estimating the susceptibility of agricultural soils to erosion, they may be ineffective as indicators of trail degradation in which rill- and gully-type erosional processes are important components.

Tread compaction on the other hand does bear some relationship to organic matter content and to a lesser extent to soil textural characteristics. A significant positive correlation ($r=0.38$; $p<0.01$) between organic matter content and percent increase in penetration resistance can be explained by the role of organic matter in facilitating the absorption of water and promoting lower soil density, hence increasing the susceptibility to compaction when trampled. There was also evidence that clay loams were less susceptible to compaction than were loams or sandy loams (the percentage of such sites exhibiting degradation being 27, 33 and 43 respectively).

(b) Locational Factors

Elevation, aspect, relief and slope position are attributes of location. Of these, elevation is often reported as a significant factor in trail degradation (Bratton et al., 1979; Cole, 1987), though its influence in this study is negligible as altitude varied little along the trail.

Aspect can generate a set of physiographical variations such as soil moisture, soil temperature and ecosystem type, though no immediate relationship between degradation and aspect was observed along the Pat Sin Range Trail. However an interesting association was observed when geology was included, with the proportion of degraded sites on western facing slopes being double that on eastern facing slopes within the volcanics. This association, whilst possibly reflecting the dip slope, is more likely to reflect user behaviour. Most hikers approach the trail from the east (from Hsien Ku Fung) and eastern slopes were mainly subject to uphill walking as opposed to the predominantly downward walking on the western slopes. It has been documented that downhill walking is more damaging to trails (Bayfield, 1973; Weaver and dale, 1978)

Both trail and terrain slopes were measured, of which trail slope statistically correlated significantly with trail width, maximum incision, trail cross-sectional area, surface roughness, trail compaction and the summary Degradation Scores within the volcanic rock environments, and with maximum incision depth and surface roughness within the sedimentary rock environments. An example of the sort of relationships that were derived is provided in Figure 4. Most of these relationships can be explained as a function of the increased erosion potential (Figure 5), though this does not readily explain the relationship between trail slope and trail width. Once again this more probably reflects user behaviour, as the shorter pace length and halting behaviour of people on steeper slopes has been observed to cause considerable damage. Moreover, when faced with the actual (or perceived) steepness of some slopes, hikers tend to seek the safer footing of the tread grass interface. This is particularly pronounced when hikers are looking downwards.

The contrasting observations for the volcanic and sedimentary environments are partly explained by the inherently higher susceptibility to erosion of the volcanic derived soil. Moreover, the finer texture of the volcanics would promote slippery conditions

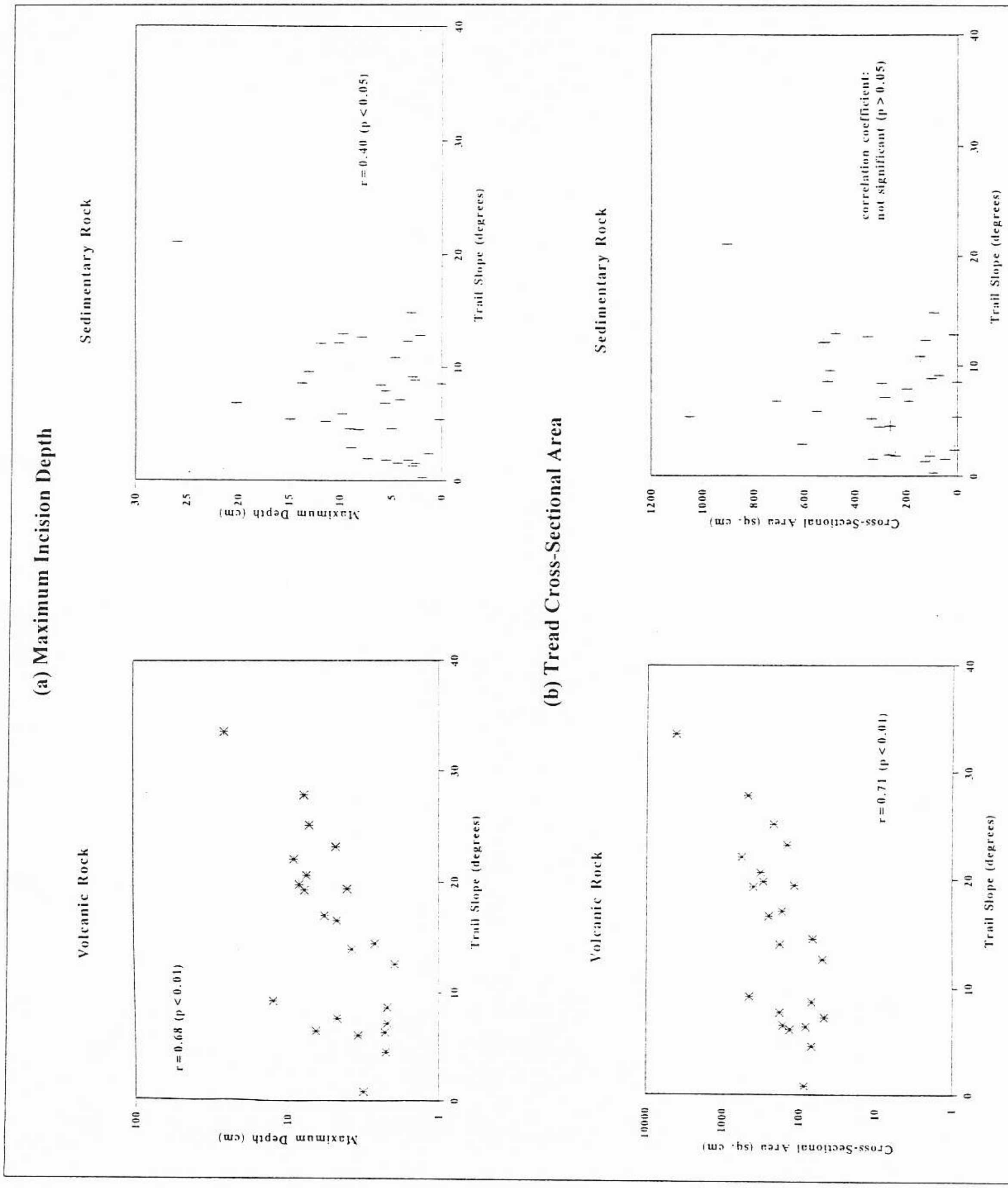

Figure 4 - Relationship between trail slope and maximum incision depth, and between trail slope and tread cross-sectional area, by geology.

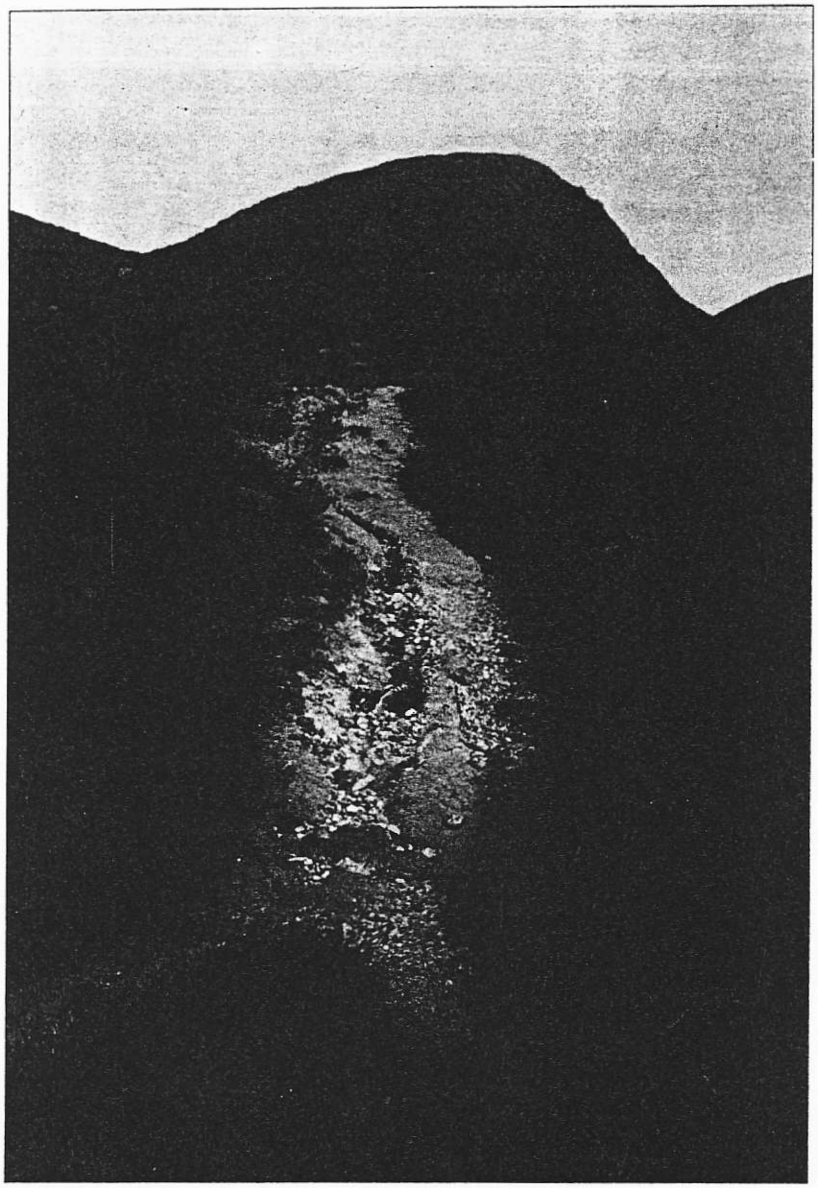

Figure 5 - Rutted trail segment on steep slopes in the vicinity of Wong Leng.

when wet and encourage off-trail wandering behaviour on steeper ground.

Trail position is yet another locational factor that influences degradation and it has been generally observed that direct ascent trails (those that are aligned with the hillslope) are more prone to damage than the oblique or contour trails. At a general level this was also observed along the Pat Sin Range, though once again more so within the volcanic trail segments. It is, however, difficult to clearly separate trail position from trail slope and a high degree of inter-correlation between these two variables is possible.

Management Implications

Trail degradation, in its many forms, affects both the quality of the environment and the recreational experience. Within the grassy hill settings of many of Hong Kong's country parks, trails are clearly observable and degradation has an aesthetic impact well beyond its immediate locality. Park managers need information on the status, causal factors and processes of degradation, and geomorphologists clearly have a role to play in such investigations.

The Pat Sin Range trail is generally in good condition though severe degradation was recorded at a number of sites. As trail slope was the single most useful predictor of a range of degradation indicators immediate attention should be directed towards steep, direct-ascent trail segments (slopes > 20°), particularly within volcanic settings. Where possible, these trails should be realigned obliquely at sidehill locations and maintained in such a way that hikers perceive safe footing. With respect to practical management applications it is apparent that the government's educational 'package' for hikers focuses on the reduction of littering and hill fires, with minimal attention to a responsible 'hiking code' of behaviour that emphasises trail maintenance and off-trail conduct.

It is recommended that Country Park brochures and Visitors Centres should promote this aspect of environmental consciousness by including sections on individual responsibility for trail maintenance and erosional control. Given the rapidly increasing pressure on the countryside this educational campaign needs to begin as soon as possible.

Further studies are also under way. In particular a very detailed monitoring programme of Tap Mun Island trails is nearing completion (Ho, in prep.). Using a micro-profiler and sediment traps, very precise measurements of erosion have been related to user intensity. Nevertheless, some of the more severely eroded trails are to be found in granitic terrains and as yet there remains little information on trail degradation in these environments.

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